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Study of Semiconductor Clusters by Local Inverse Photo Emission

ONR

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We have completed the project of building the first system consisting of a scanning tunneling microscope operating in ultra-high vacuum, and all the components, shown in Figure 1, are now operational. STM images of charge-density waves in UHV have been successfully obtained, as shown in Figure 2. We have developed and operated two other systems that enable us to perform the task delineated in the original ONR proposal. The second system is a computerized nanolithography station where computer generated patterns drive the STM tip, which deposits atoms at the pre-prescribed locations, as shown in Figure 3. The third system measures the photon emission from nanostructures using a cooled photomultiplier, a photon counter, and an image processor, as shown in Figures 4-6. We are currently writing several papers that describe the theory of photon emission from STM-deposited patterns and the various experiments performed with these three systems. Enclosed is a list of publications describing our STM work. Future plans call for the refinement of the experiments where clusters are written and their light emission recorded and analyzed topographically and spectroscopically.

STM Publications

Semiconductors and Surfaces

Dror Sarid, Brian P. McGinnis, and Tammy D. Henson, "Four-wave mixing and scanning tunneling microscopy of semiconductor clusters," Opto-Electronics and Laser Applications in Science and Engineering, O-E LASER'88, SPIE, Los Angeles 10-17 January (1988).

Dror Sarid, Tammy D. Henson, L. Stephen Bell, and Claude J. Sandroff, "Scanning tunneling microscopy of semiconductor clusters," J. Vac. Sci. and Tech. A **6**, 424 (1988).

Dror Sarid, Tammy D. Henson, Neal Armstrong, and L. Stephen Bell, "Probing of Basal Planes of MoS_2 by Scanning Tunneling Microscopy", Appl. Phys. Lett. **52**, 2252 (1988).

Tammy D. Henson, Dror Sarid, and L. Stephen Bell, "Scanning Tunneling Microscopy of Layered-Structure Semiconductors," J. Royal Microscopic Society, STM-88 (1988).

T. Iwabuchi, C. Chuang, G. Khitrova, M. E. Warren, A. Chavez-Pirson, H. M. Gibbs, D. Sarid, and M. Gallagher, "Fabrication of GaAs nanometer structures by dry etching," SPIE (1990).

Dror Sarid, "First Hologram of a Cluster Showing Single Atoms," Optics News (1988).

T. Chen, S. Howells, M. Gallagher, L. Yi, and D. Sarid, "Internal Structure and Two-Dimensional Order of Monolayer C_{60} Molecules Observed with STM," submitted to J. Vac. Sci. Technol. (1991).

T. Chen, S. Howells, M. Gallagher, L. Yi, and D. Sarid, "Modelling of Internal Structure of Monolayer C_{60} on a Gold Substrate," Proc. MRS (1991).

Instrumentation and Theory

Dror Sarid, Douglas Iams, Volker Weissenberger, and L. Stephen Bell, "Compact Scanning Force Microscope Using a Diode Laser," Opt. Lett. **28** 335 (1988).

Dror Sarid, Volker Weissenberger, Douglas A. Iams, and Jeffery T. Ingle, "Theory of the laser diode interaction in a scanning force microscope," IEEE J. Quant. Electr. **25**, 1968 (1989).

Dror Sarid, Douglas Iams, Jeffery Ingle, Volker Weissenberger, and Josef Ploetz, "Performance of a Scanning Force Microscope Using a Laser Diode," J. Vac. Sci. Tech. **8**, 378 (1989).

S. Howells, M. Gallagher, L. Yi, T. Chen, and D. Sarid, "Enhanced Effects with Scanning Force Microscopy," submitted to Appl. Phys. (in press, 1991).

L. Yi, D. Sarid, S. Howells, M. Gallagher, and T. Chen, "Combined STM-AFM for Magnetic Applications," Proc. Engineering Foundation . :anned Probe Microscopies) (1991).

Review

Dror Sarid, *Scanning Force Microscopy*, Oxford University Press, 1991.

Dror Sarid and Virgil Elings, "Review of Scanning Force Microscopy," J. Vac. Sci. Technol., in print (1991).

Biology

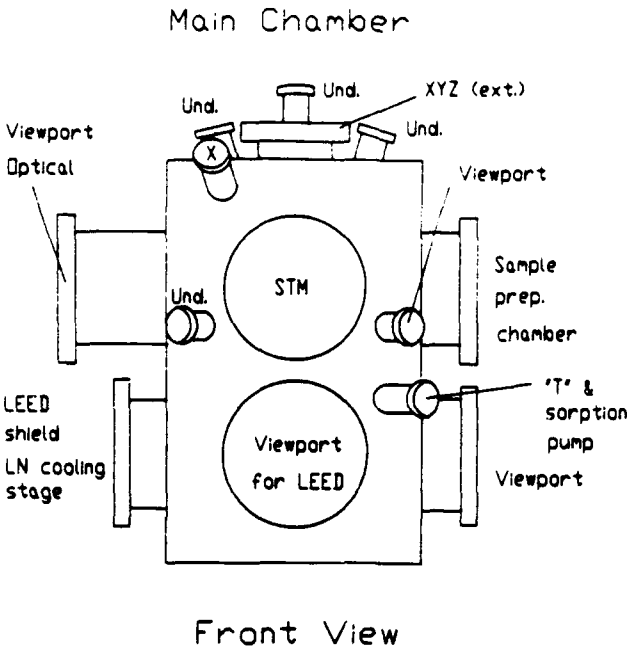
Dror Sarid, Edmond H. Thall, Douglas A. Iams, Jeffery T. Ingle, Tammy D. Henson, Y. C. Lee, and L. Stephen Bell, "Scanning Tip Microscopy with Applications to Biology," SPIE, Los Angeles, January (1989).

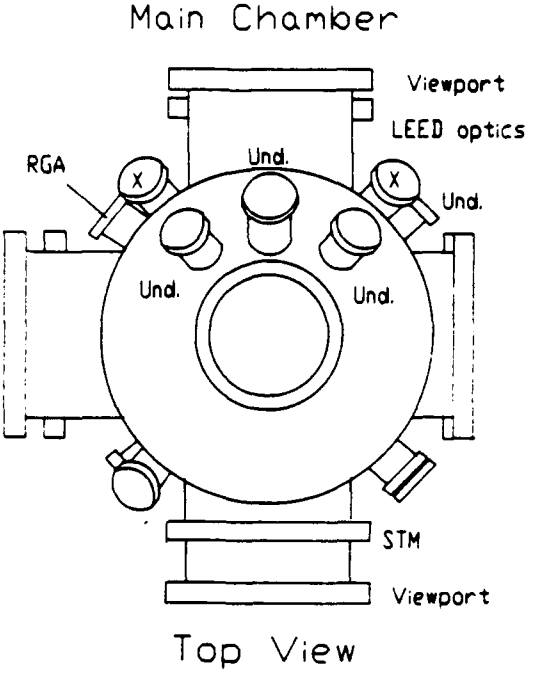
S. R. Hameroff, Y. Simic-Kristic, L. A. Venetti, Y. C. Lee, Dror Sarid, J. Weidmann, V. Elings, K. Kjoller, and R. S. McCuskey, "STM of Cytoskeletal Proteins: Microtubules and Intermediate Filaments," J. Vac. Sci. Technol. **8**, 687 (1990).

L. A. Vernetti, Y. C. Lee, D. Sarid, R. McCuskey, A. J. Gandolfi, and S. R. Hameroff, "Intra-protein structural detail of cytokeratin resolved by STM," J. Vac. Sci. Technol., in print (1990).

L. A. Vernetti, Dror Sarid, A. J. Gandolfi, A. E. Cress, R. B. Nagel, R. McCuskey, and S. R. Hameroff, "Molecular resolution of Cytokeratin Proteins by Scanning Tunneling Microscopy," Biochemistry, submitted (1990).

A. E. Cress, L. A. Vernetti, P. A. Bauman, R. A. Roberts, D. Sarid, and W. S. Dalton, "Cytokeratin is a site of chemotherapeutic Drug Damage in a Human Colon Tumor Cell Line," AACR (1990).





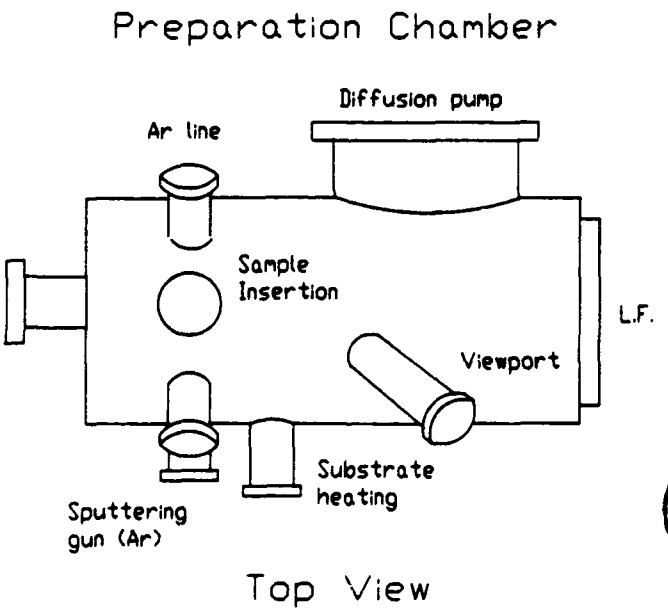


Figure 1. The experimental system comprising of: (1) UHV chamber, (2) preparation chamber, (3) LEED, (4) Auger, (5) three Knudsen cells, (6) electron heating, (7) cleaving, (8) mass spectroscopy, (9) sputtering, and (10) scanning tunneling microscopy.

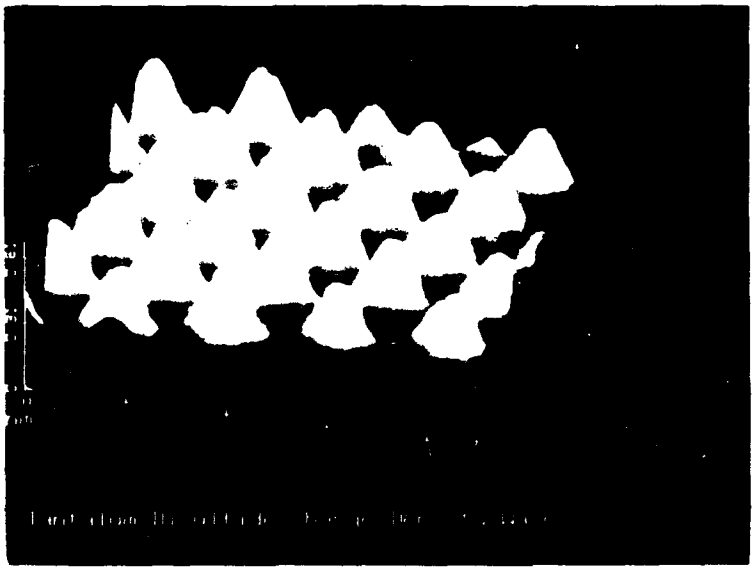


Figure 2. STM image of charge-density waves on TaS_2 crystal in UHV.

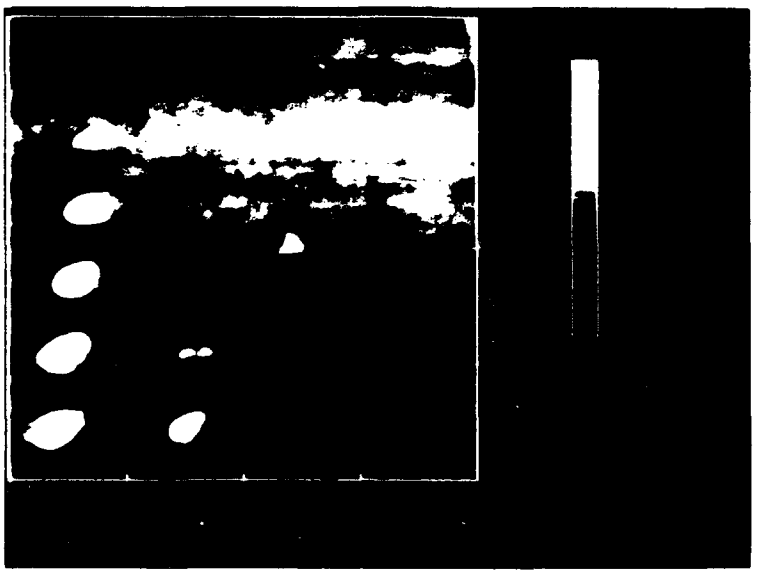


Figure 3. Nanolithography with gold tip and a crystalline gold sphere showing an STM image of an array of dots.

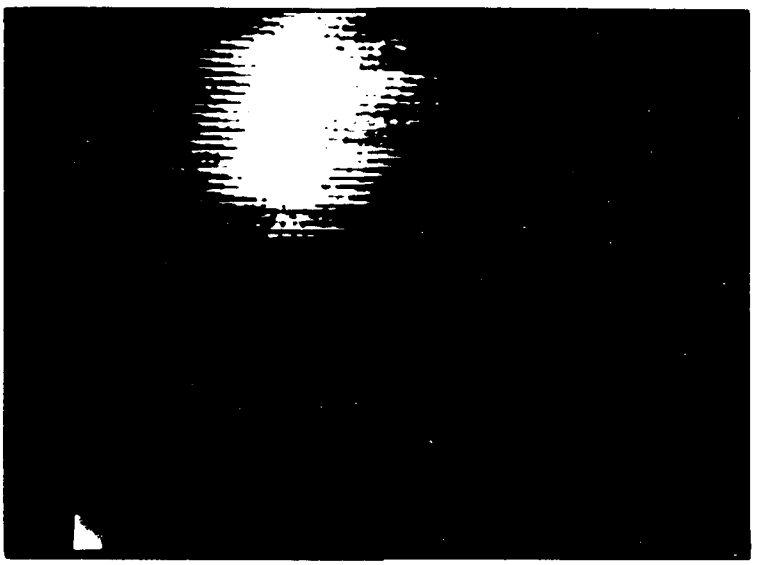


Figure 4. An STM image of a single gold structure.

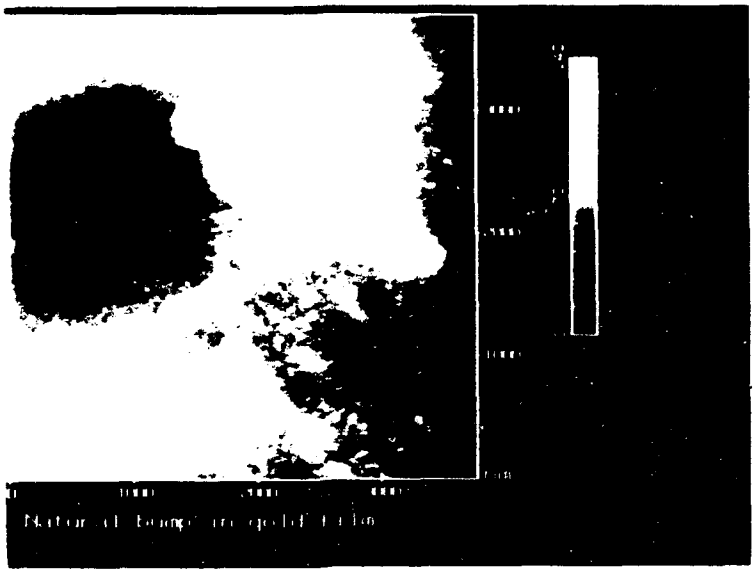


Figure 5. An image due to photon emission from the structure of Figure 3 using the STM.

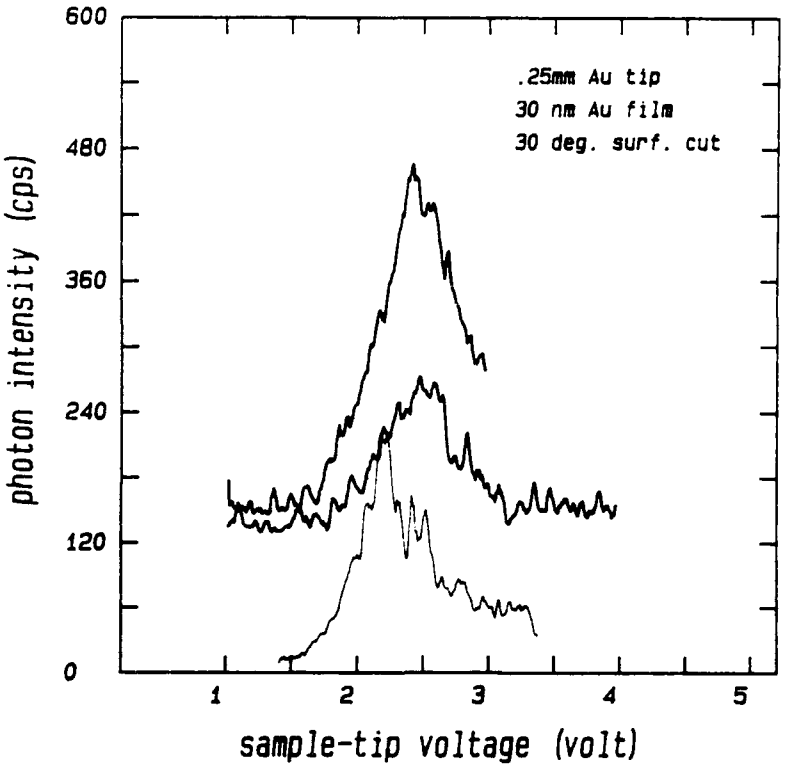


Figure 6. The spectroscopy of the photon emission using the STM.